NATIONAL INSTITUTE OF TECHNOLOGY DURGAPUR

DEPARTMENT OF PHYSICS

Revised Curriculum and Syllabi

Program Name
Master of Technology in Advanced Materials Science and Technology
Effective from the Academic Year: 2021-2022

Recommended by DPAC	: 31.07.2021
Recommended in PGAC	: 16.08.2021
Approved by the Senate	: 22.08.2021

TABLE OF CONTENTS

PROGRAM OBJECTIVES*

PO1 : Ability to independently carry out research/investigation and development work to solve practical problems.

PO2 : Ability to communicate effectively, i.e., write and present a substantial technical report/document.

PO3: Ability to demonstrate a degree of mastery in the field of advanced materials science and technology at a level higher than that for a bachelor program.

PO4 : Ability to solve scientific (experimental and theoretical) tasks both as a member of a team and as a leader of the team.

PO5 : Ability to identify and use the appropriate modern techniques, skills, and tools to offer technical solutions to engineering problems.

*The POs have been prepared in accordance with the Self-Assessment Report (SAR) format of the National Board of Accreditation (NBA)

DEPARTMENT OF PHYSICS
M. Tech in Advanced Materials Science and Technology

CURRICULUM

SEMESTER-I

Sl. No.	Subject Code	Subject	L - T - P	Credit
1	PH1001	Fundamentals of Materials Science	3 - 0 - 0	3
2	PH1002	Materials for Engineering Applications	3 - 1 - 0	4
3	PH1003	Engineering Mathematics & Numerical Analysis for Material Science	3 - 1 - 0	4
4	PH903X	Elective - I	3 - 0 - 0	3
5	PH903X	Elective - II	3 - 0 - 0	3
6	PH1051	General Materials Science Lab	0 - 0 - 4	2
7	PH1052	Materials Synthesis & Characterization Lab	0 - 0 - 4	2
TOTAL				**21**

SEMESTER-II

Sl. No.	Subject Code	Name of the Subject	L - T - P	Credit
1	PH2001	Techniques of Materials Characterization	3 - 1 - 0	4
2	PH903X	Elective - III	3 - 0 - 0	3
3	PH903X	Elective - IV	3 - 0 - 0	3
4	PH903X	Elective - V	3 - 0 - 0	3
5	PH903X	Elective - VI	3 - 0 - 0	3
6	PH2051	Computational Lab	0 - 0 - 4	2
8	PH2053	Minor Project with Seminar	0 - 0 - 6	3
TOTAL				**21**

SEMESTER-III

Sl. No.	Subject Code	Name of the Subject	Credit
1	PH9071	Audit Lectures/Workshop	0
2	PH3051	Dissertation - I	12
3	PH3052	Seminar – Non-Project / Evaluation of Summer Training	2
TOTAL			**14**

SEMESTER-IV

Sl. No.	Subject Code	Name of the Subject	Credit
1	PH4051	Dissertation – II / Industrial Project	12
2	PH4052	Project Seminar	02
			14
TOTAL			**69-71**

LIST OF ELECTIVE PAPERS

Sl. No.	Subject Code	Name of the Subject
1	PH9030	X-ray Diffraction & Structure of Materials
2	PH9031	Optoelectronic Materials and Devices
3	PH9032	Nanomaterials – Science & Technology
4	PH9033	Mechanical Behavior of Materials
5	PH9034	Semiconductor Materials and Device Technology
6	PH9035	Materials for Energy Applications
7	PH9036	Nuclear Reactor Materials
8	PH9037	Thin-film Materials Technology
9	PH9038	Biomaterials
10	PH9039	Non-Destructive Testing
11	NPTEL	Fundamentals and Applications of Dielectric Ceramics
12	NPTEL	Scanning Electron / Ion / Probe Microscopy in Materials Characterization

LIST OF CORE PAPERS WITH THEIR DEVELOPERS' NAMES

Subject code	Name of the Subject	L - T - P	Credit	Name of the developer
PH1001	Fundamentals of Materials Science	3 - 0 - 0	3	Prof. A. K. Meikap & Dr S. Sahoo
PH1002	Materials for Engineering Applications	3 - 1 - 0	4	Prof. A. K. Chakraborty
PH1003	Engineering Mathematics & Numerical Analysis for Material Science	3 - 1 - 0	4	Dr. M. K. Mandal Dr. S. Ghosh Dr. H. Subramanian
PH2001	Techniques of Materials Characterization	3 - 1 - 0	4	Prof. A. K. Chakraborty Dr. Abhijit Ghosh

LIST OF ELECTIVE PAPERS WITH THEIR DEVELOPERS' NAMES

Subject Code	Name of the Subject	L-T-P	Credit	Name of the developer
PH9030	X-ray Diffraction & Structure of Materials	3 - 0 - 0	3	Dr. H. Chaudhuri Dr. H. Subramanian
PH9031	Optoelectronic Materials and Devices	3 - 0 - 0	3	Prof. P. Kumbhakar & Dr. H. Chaudhuri
PH9032	Nano materials – Science & Technology	3 - 0 - 0	3	Prof. A. K. Chakraborty Dr. A. Mondal
PH9033	Mechanical Behavior of Materials	3 - 0- 0	3	Dr. S. Basu & Dr. A. Ghosh
PH9034	Semiconductor Materials and Device Technology	3 - 0 - 0	3	Dr. A. Mondal & Prof. A. K. Meikap
PH9035	Materials for Energy Applications	3 - 0 - 0	3	Prof. A. K. Chakraborty & Dr. A. Mondal

PH9036	Nuclear Reactor Materials	3 - 0 - 0	3	Prof. A. K. Chakraborty & Dr. S. Das
PH9037	Thin-film Materials Technology	3 - 0 - 0	3	Prof. A. K. Meikap & Dr. A. Mondal
PH9038	Biomaterials	3 - 0 - 0	3	Dr. S. Ghosh Dr. H. Subramanian
PH9039	Non-Destructive Testing	3 - 0 - 0	3	Dr. A. Ghosh Dr. S. Basu

LIST OF LABORATORY & SESSIONAL PAPERS

SUBJECT CODE	SUBJECT	L-T-P	CREDIT
PH1051	General Materials Science Lab	0 - 0 – 4	2
PH1052	Materials Synthesis & Characterization Lab	0 - 0 – 4	2
PH2051	Computational Lab	0 - 0 – 4	2

LIST OF PROJECT/DISSERTATION/SEMINAR PAPERS

SUBJECT CODE	SUBJECT	L-T-P	CREDIT
PH2053	Minor Project with Seminar	0 - 0 – 6	3
PH9071	Audit Lectures / Workshops	0 - 0 –0	0
PH3051	Dissertation - I	0 - 0 – 24	12
PH3052	Seminar-Non-Project / Evaluation of Summer Training	0 - 0 – 4	2
PH4051	Dissertation – II / Industrial Project	0 - 0 – 24	12
PH4052	Project Seminar	0 - 0 – 4	2

<table>
<tr><td colspan="8">Department of Physics</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>PH1001</td><td>Fundamentals of Materials Science</td><td>PCR</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="2">Pre-requisites</td><td colspan="6">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="2">NIL</td><td colspan="6">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">On completion of the course the learner shall be able to:
• CO1: Describe fundamentals of materials science.
• CO2: Analyze the basic concepts of thermodynamic functions and their applications for crystalline and non-crystalline materials.
• CO3: Explain various structural, thermal, electronic and magnetic properties of materials.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Lattice vibration: Theory of lattice vibration, Born Karman condition, phonon frequency distribution and dispersion relations, interaction of X-rays and neutrons with phonons. [8]
Mossbauer effect: Mossbauer effect, Resonance Absorption, Study of atomic motion in solids, Debye Waller factor and application of Mossbauer effect. [4]

Thermodynamics & Phase transformations: Concept of heat and work in Thermodynamics, Thermodynamic Systems, Zeroth Law of Thermodynamics. Concepts of Temperature, Differential form of the First Law, Statements of Second law, concept of entropy, enthalpy. Thermodynamic functions and relations for a crystal. Phase transformations & multiphase equilibrium. [10]
Electronic energy band theory: Energy band theory, classical free electron theory of solids, Sommerfeld quantum free electron theory of a solid, Bloch wavefunction for a periodic potential, Kronig Penny model and energy bands. Fermi energy and Fermi surfaces, effective mass of an electron, Brillouin zones & reciprocal lattice. [10]
Electronic properties of Solids: Transport equation in presence of magnetic field, cyclotron resonance, energy levels and density of states in presence of magnetic fields. Landau diamagnetism, spin paramagnetism, de-Haas van-Alphen effect. magnetoresistance, classical and quantum Hall effect. [10]</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">Text Books:
1. Aschroft & Mermin – Solid State Physics
2. V. Raghavan - Materials Science and Engineering: a first course
Reference Books:
1. M. S. Rogadski& S. B. Palmer - Solid State Physics
2. Wallace – Thermodynamics of Crystals.
3. M. N. Saha and B. N. Srivastava – A Treatise on Heat
4. Animalu – Intermediate Quantum Theory of Crystalline Solids</td></tr>
</table>

Mapping of CO (Course Outcome) and PO (Programme Outcome)

POs / COs	PO1	PO2	PO3	PO4	PO5
CO1	2	2	2	2	2
CO2	2	2	2	1	2
CO3	2	2	1	2	2

Correlation levels 1, 2 or 3 as defined below :

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

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<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>PH1002</td><td>Materials for Engineering Applications</td><td>PEL</td><td>3</td><td>1</td><td>0</td><td>4</td><td>4</td></tr>
<tr><td colspan="2">Pre-requisites</td><td colspan="6">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="2">NIL</td><td colspan="6">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">On completion of the course the learner shall be able to:
• CO1: Discuss different techniques for preparation and fabrication of engineering materials.
• CO2: Explain different modern techniques for characterization of polymer, composite, glassy, electrical and optical materials.
• CO3: Identify appropriate material types for solving real life engineering problems.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Introduction to Materials: The material world, types of materials, Introduction to metals, ceramics, polymers, composites, semiconductors, their physical properties, and selection. [5]

Structural Materials: Metals and alloys, Ferrous alloys, Steel, the Phase rule and phase diagrams of Fe-C system and common non-ferrous alloys, Eutectic, Eutectoid, Peritectic diagrams, TTT diagram, the Liver rule. [12]

Polymers: Types of polymers, polymerizations processes, step polymerizations and addition polymerization, degradation and stabilization of polymers, conducting polymers, common polymers, their synthesis, properties and applications. [11]

Ceramics & glasses: Types of ceramics, phase diagrams of common ceramic alloys, properties of common ceramics & glasses, their common applications and processing methods. [7]

Composites: Types of composites, conventional composites, fiber reinforced composites, nanocomposites, property averaging by Rule of Mixture, isostress & isostrain loading, Interfacial strength, mechanism of reinforcement, common structural composites, their processing and applications. [8]

Electrical Materials: Conductors, Conductivity and its temperature dependency, semiconductors, Superconductors. [5]

Optical Materials: Optical properties, color, luminescence, reflectivity, transparency, opacity, etc., optical systems and devices, Laser materials, optical fibers, liquid crystal displays, photoconductors. [8]</td></tr>
</table>

Text Books, and/or reference material	**Text Books:** 1. J. F. Shackelford, M. K. Muralidhara, *Introduction to Materials Science for Engineers* 2. R. Balasubramaniam, *Callister's Materials Science & Engineering* **Reference Books:** 1. V. Raghavan - *Materials Science and Engineering: a first course* 2. W.F. Smith, J. Hashemi, R. Prakash, *Materials Science & Engineering* 3. Rolf E. Hummel, *Understanding Materials Science : History, Properties, Applications* 4. John Martin, *Materials for Engineering* 5. J. Simmons, K Potter, *Optical Materials* 6. Fuxi Gan, *Laser Materials* 7. A. K. Bhargava, *Engineering Materials*

Mapping of CO (Course Outcome) and PO (Programme Outcome)

POs / COs	PO1	PO2	PO3	PO4	PO5
CO1	3	1	2	1	3
CO2	3	1	1	2	3
CO3	3	1	2	2	3

Correlation levels 1, 2 or 3 as defined below :

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

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<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>PH1003</td><td>Engineering Mathematics and Numerical Analysis for Materials Science</td><td>PEL</td><td>3</td><td>1</td><td>0</td><td>4</td><td>4</td></tr>
<tr><td colspan="2">Pre-requisites</td><td colspan="6">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="2">NIL</td><td colspan="6">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">On completion of the course the learner shall be able to:
• CO1: Learn advanced mathematical techniques necessary to solve engineering problems.
• CO2: Devise algorithms for writing computer programs to solve problems using numerical techniques and scientific software like Scilab, Python, etc.
• CO3: Interpret and solve problems related to the properties of materials and applications.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Mathematical Preliminaries: Linear algebra, Matrix manipulations, eigenvalue decomposition. Probability, Introduction to random variables with applications. Differential equations (applied to heat flow and diffusion). Fourier Series and applications. Discrete Fourier Transform, Integral transforms (Fourier and Laplace), Convolution theorem. Nonlinear methods (Logistic map). [15]
Programming Methodology: Problem solving algorithm, analysis of algorithms and programming, flow charts higher level languages. Basics of programming, conditional and unconditional jumps, iteration, loops, functions, structure & object-oriented programming. [15]
Numerical Techniques: Application of Programming (in Scilab/Python) to the following problems: Errors in numerical computation, Solutions of equations by iteration, Finite differences, Interpolation, Numerical integration and differentiation, Numerical solution of first and second order differential equations, Systems of linear equations, Methods of least squares. [15]
Engineering Applications: Simulation techniques, nonlinear curve fitting, Implementation of mathematical techniques in Python/Scilab. [11]</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">Text Books:
(1) Arfken and Weber, Mathematical Methods for Physicists, Elsevier.
(2) J H Mathews & K D Fink, Numerical Methods Using Matlab.

Reference Books:
(1) Numerical Recipes: The Art of Scientific Computing, W. H. Press et al.</td></tr>
</table>

Mapping of CO (Course Outcome) and PO (Programme Outcome)

POs / COs	PO1	PO2	PO3	PO4	PO5
CO1	1	1	1	1	2
CO2	1	1	2	2	2
CO3	2	1	2	2	2

Correlation levels 1, 2 or 3 as defined below :

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Department of Physics							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
PH1051	**General Materials Science Lab**	PCR	0	0	4	4	2
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NIL		CT+EA					
Course Outcomes	On completion of the course the learner shall be able to: • **CO1:** Measure materials properties using experimental techniques. • **CO2:** Demonstrate the operating knowledge of materials. • **CO3:** Relate the concepts learned with the functioning of everyday devices.						
Topics Covered	1. Band Gap Measurement of semiconductor 2. Determination of Refractive index by Abbe refractometer of different liquid samples 3. Determination of Gaussian beam distribution of He-Ne Laser beam 4. To study the Hall effect of a given semiconductor materials 5. To determine the Hysteresis loop of a ferromagnetic materials 6. To determine magneto resistance of n-type semiconductor materials 7. To study the Electrolytic conduction of ionic crystals 8. Determination of efficiency of a solar cell						
Text Books, and/or reference material	**Text Books:** 1. An advanced course in practical physics, Chattapadhyay and Rakshit. 2. Advanced practical Physics, K. G. Mazumdar. **Reference Books:** 1. A Textbook of Advanced Practical Physics, S. K. Ghosh.						

Mapping of CO (Course Outcome) and PO (Programme Outcome)

POs / COs	PO1	PO2	PO3	PO4	PO5
CO1	2	3	1	3	2
CO2	2	3	1	3	2
CO3	2	3	1	3	2

Correlation levels 1, 2 or 3 as defined below :

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Department of Physics								
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
PH1052	**Materials Synthesis & Characterization Lab**	PCR	0	0	4	4	2
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NIL		CT+EA					

Course Outcomes	On completion of the course the learner shall be able to: • **CO1:** Measure some basic properties of polymers and semiconductor nanoparticles. • **CO2:** Demonstrate the experimental technique for material synthesis. • **CO3:** Relate the concepts learned with the functioning of devices used in daily life.
Topics Covered	1. Synthesis of a polymer composite 2. Synthesis of a semiconductor nanoparticles by chemical method 3. Preparation of metal oxide semiconductor thin film 4. Determination of optical absorption characteristics 5. Electrical transport properties of polymer composite 6. Electrical transport properties of thin film 7. Determination of thermal stability of polymer composite 8. Structural characterization of nanomaterials by XRD technique 9. Spectral characterization of Si & Ge photo detectors
Text Books, and/or reference material	**Text Books:** 1. An advanced course in practical physics, Chattapadhyay and Rakshit. 2. Advanced practical Physics, K. G. Mazumdar. **Reference Books:** 1. A Textbook of Advanced Practical Physics, S. K. Ghosh.

Mapping of CO (Course Outcome) and PO (Programme Outcome)

POs / COs	PO1	PO2	PO3	PO4	PO5
CO1	2	3	1	3	2
CO2	2	3	1	3	2
CO3	2	3	1	3	2

Correlation levels 1, 2 or 3 as defined below :

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<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>PH2001</td><td>Techniques of Materials Characterization</td><td>PEL</td><td>3</td><td>1</td><td>0</td><td>4</td><td>4</td></tr>
<tr><td colspan="2">Pre-requisites</td><td colspan="6">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="2">NIL</td><td colspan="6">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">• CO1: Explain different tools, techniques for characterization of different materials.
• CO2: Demonstrate knowledge of different optical and electron microscopic techniques (TEM, SEM, SPM) for characterization of different materials.
• CO3: Discuss different thermal methods (DTA, TGA, DSC, TMA and DMA) for characterization of materials.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Introduction - definition; importance and application. Principles and general methods of compositional, structural and defect characterization. [3]
Diffraction techniques - X-ray, electron and neutron diffraction [4]
Microscopy I - optical, electron (TEM & SEM) including image analysis, fracture surface analysis and electron microprobe analysis [14]
Microscopy II – scanning probe methods (STM, AFM, EFM, MFM etc.) [8]
Optical spectroscopies - UV, visible, IR and Raman spectroscopies [8]
Electron spectroscopies - Auger and photoelectron spectroscopies [8]
Resonance spectroscopies - NMR, ESR, Optical and Mossbauer spectroscopies [7]
Thermal methods - DTA, TGA, DSC, TMA and DMA. [8]
Mechanical methods: measurement of tensile & flexural moduli, strength, fatigue, creep, fracture toughness, hardness etc. [5]</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">Text Books:
1. Materials Characterization-Yang Lang
2. Dieter K. Schroder - Semiconductor material and device characterization
Reference Books:
1. Materials Characterization Techniques- Sam Zhang, Lin Li, Ashok Kumar
2. Auger and X-ray photoelectron spectroscopy- D. Briggs and M. P. Seah
3. An Introduction to Material Characterization- P. R. Khangaonkar
4. Characterization of Materials, (2 Volume Set), E. N. Kauffmann (Editor)
5. Physical Principles of Electron Microscopy- R. F. Egerton</td></tr>
</table>

Mapping of CO (Course Outcome) and PO (Programme Outcome)

POs / COs	PO1	PO2	PO3	PO4	PO5
CO1	2	1	2	2	3
CO2	2	1	2	2	3
CO3	2	1	2	2	2

Correlation levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

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<tr><td colspan="9">Department of Physics</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>PH2051</td><td>Computational Lab</td><td>PCR</td><td>0</td><td>0</td><td>4</td><td>4</td><td>2</td></tr>
<tr><td colspan="2">Pre-requisites</td><td colspan="6">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="2">NIL</td><td colspan="6">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">• CO1: Demonstrate an ability to identify appropriate algorithms for computationally solving various physics and engineering models.
• CO2: Express the concepts of computer programs and to implement various algorithms for modeling simple physical systems.
• CO3: Develop a deeper understanding of fundamental concepts in Material Science and Technology through computational simulations.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">1. Introduction to Scilab, Python and MATLAB
2. To Plot the Fermi- Dirac Probability distribution vs Energy Characteristics of an intrinsic semiconductor at room temperature using Scilab/Python/MATLAB.
3. To Plot the Fermi- Dirac Probability distribution vs Energy Characteristics of n-type semiconductor at room temperature using Scilab/Python/MATLAB.
4. To Plot the Fermi- Dirac Probability distribution vs Energy Characteristics of p-type semiconductor at room temperature using Scilab/Python/MATLAB.
5. To plot the carrier concentration vs temperature characteristics for an intrinsic semiconductor
6. Plotting of state variables (Phase space & state space) of a given dynamical system
7. Estimate of Hurst exponent and Lyapunov exponent (nonlinear statistics) of a dynamical system
8. Numerical solution of different integral and differential equations using Scilab/Python/MATLAB.</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">Text Book: (1) A First Course in Computational Physics, Paul L. DeVries, Javier E. Hasbun, ISBN: 978-0-7637-7314-4.
(2) Computational Materials Science: An Introduction, June Gunn Lee, CRC Press.
Reference Book: (1) Computational Physics , Landau Rubin H, ISBN: 9783527413157</td></tr>
</table>

Mapping of CO (Course Outcome) and PO (Programme Outcome)

POs / COs	PO1	PO2	PO3	PO4	PO5
CO1	2	2	1	2	2
CO2	2	2	2	3	2
CO3	3	2	2	3	2

Correlation levels 1, 2 or 3 as defined below :

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Department of Physics								
Course Code	**Title of the course**	**Program Core (PCR) / Electives (PEL)**	**Total Number of contact hours**				**Credit**
			Lecture (L)	**Tutorial (T)**	**Practical (P)#**	**Total Hours**	
PH2053	**Minor Project With Seminar**	PCR	0	0	6	6	3
Pre-requisites		Course Assessment methods: (Continuous evaluation (CE) and end assessment (EA))					
NIL		CE+EA					
Course Outcomes	On completion of the course the learner shall be able to: **CO1:** Effectively present the knowledge gain on a specific scientific topic through critical thinking. **CO2:** Develop oral skill for scientific communication and presentation **CO3:** Develop time management skill.						
Topics Covered	Topics will be provided						
Text Books, and/or reference material	To be notified separately.						

Mapping of CO (Course Outcome) and PO (Programme Outcome)

POs / COs	PO1	PO2	PO3	PO4	PO5
CO1	2	3	2	2	3
CO2	2	3	2	2	3
CO3	3	3	2	3	3

Correlation levels 1, 2 or 3 as defined below :

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<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)#</td><td>Total Hours</td></tr>
<tr><td>PH3051</td><td>Dissertation-I</td><td>PCR</td><td>0</td><td>0</td><td>24</td><td>24</td><td>12</td></tr>
<tr><td colspan="2">Pre-requisites</td><td colspan="6">Course Assessment methods: (Continuous evaluation (CE) and end assessment (EA))</td></tr>
<tr><td colspan="2">NIL</td><td colspan="6">CE+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">On completion of the course the learner shall be able to:
CO1: Identify, summarize and critically evaluate relevant literature and write a review.
CO2: Undertake problem identification and formulation.
CO3: Effectively write scientific findings in a systematic and logical sequence.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Topics will be provided</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">To be notified separately.</td></tr>
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Mapping of CO (Course Outcome) and PO (Programme Outcome)

POs / COs	PO1	PO2	PO3	PO4	PO5
CO1	2	2	2	2	2
CO2	2	2	2	2	2
CO3	3	3	3	3	3

Correlation levels 1, 2 or 3 as defined below :

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Department of Physics							
Course Code	**Title of the course**	**Program Core (PCR) / Electives (PEL)**	**Total Number of contact hours**				**Credit**
			Lecture (L)	**Tutorial (T)**	**Practical (P)#**	**Total Hours**	
PH3052	**Seminar – Non Project / Evaluation of Summer Training**	PCR	**0**	**0**	**4**	**4**	**2**
Pre-requisites		Course Assessment methods (As per PG regulation)					
NIL		AS PER PG REGULATION					

Course Outcomes	On completion of the course the learner shall be able to: • **CO1:** Defend their knowledge to an expert committee. • **CO2:** Develop communication skill. • **CO3:** Create good presentation through soft skills.
Topics Covered	Topics will be provided
Text Books, and/or reference material	To be notified separately.

Mapping of CO (Course Outcome) and PO (Programme Outcome)

COs \ POs	PO1	PO2	PO3	PO4	PO5
CO1	2	3	3	2	2
CO2	2	3	3	3	3
CO3	2	3	3	2	2

Correlation levels 1, 2 or 3 as defined below :

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Department of Physics							
Course Code	**Title of the course**	**Program Core (PCR) / Electives (PEL)**	**Total Number of contact hours**				**Credit**
			Lecture (L)	**Tutorial (T)**	**Practical (P)#**	**Total Hours**	
PH4051	**Dissertation – II / Industrial Project**	PCR	**0**	**0**	**24**	**24**	**12**
Pre-requisites		Course Assessment methods (As per PG regulation)					
NIL		AS PER PG REGULATION					
Course Outcomes	On completion of the course the learner shall be able to: • **CO1:** Undertake problem identification, formulation and solution through scientific observation. • **CO2:** Analyze and synthesize research findings and demonstrate capability of independent research. • **CO3:** Effectively write and present scientific findings in a systematic and logical sequence.						
Topics Covered	Topics will be provided						
Text Books, and/or reference material	To be notified separately.						

Mapping of CO (Course Outcome) and PO (Programme Outcome)

POs / COs	PO1	PO2	PO3	PO4	PO5
CO1	2	3	3	2	2
CO2	3	3	3	3	2
CO3	3	3	3	3	3

Correlation levels 1, 2 or 3 as defined below :

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Department of Physics								
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)#	Total Hours	
PH4052	Project Seminar	PCR	0	0	4	4	2
Pre-requisites			Course Assessment methods (As per PG regulation)				
NIL			AS PER PG REGULATION				
Course Outcomes	On completion of the course the learner shall be able to: • **CO1:** Defend their knowledge to an expert committee. • **CO2:** Develop skill for presentation of overall scientific knowledge gained in the course of study. • **CO3:** Create critical thinking skill.						
Topics Covered	Topics will be provided						
Text Books, and/or reference material	To be notified separately						

Mapping of CO (Course Outcome) and PO (Programme Outcome)

POs / COs	PO1	PO2	PO3	PO4	PO5
CO1	2	3	3	2	2
CO2	2	3	3	3	3
CO3	2	3	3	2	2

Correlation levels 1, 2 or 3 as defined below :

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Department of Physics								
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
PH9030	**X-ray Diffraction & Structure of Materials**	PCR	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NIL		CT+EA					
Course Outcomes	• **CO1:** Demonstrate knowledge on X-ray diffraction techniques for characterizing materials (crystalline, amorphous, quasi-crystalline, polymer, nanomaterials). • **CO2:** List different techniques for extracting quantitative information about material structures by x-ray diffraction. • **CO3:** Develop an understanding of the theory of X-ray diffraction and to employ it to study novel material structures.						
Topics Covered	**Recapitulation:** Production and properties of X-ray. X-ray absorbtion, absorbtion edges, mass absorbtion coefficients. Filtering of characteristic spectra. Symmetry operations, Macroscopic symmetry, Point Group of symmetry, Microscopic symmetry, Space Group, Hermann-Mauguin symbols of Space Group. Bravais Lattice. Short-range and long-range order, Single crystal and polycrystalline state of matter. **[8]** **Kinematical theory:** Scattering by an electron, atom, atomic scattering factor, scattering by a conglomerate of atoms in regular order, scattering by a crystal, crystal structure factor, Reciprocal lattice, relations between reciprocal lattice and direct lattice vectors. Ewald's sphere, Laue conditions, Bragg's Law, Laws of systemic absences from different crystal systems. Phase identification by Hanawalt's method. Quantitative estimation of different paphases, some important applications. **[8]** **X-ray Scattering:** Scattering by conglomerate of atoms arranged irregularly, scattering by amorphous materials and liquids. Radial Distribution analysis. **[6]** **Dynamical Theory:** Scattering by large perfect crystals, Dynamical theory of X-ray diffraction, X-ray microscopy, Lang Camera, direct observation of defect parameters. Diffraction from polycrystalline materials. Fourier analysis of the diffraction profiles. Estimation of defect parameters from Four line shape analysis. **[6]** **Temperature Effect:** Effect of temperature on diffraction, Change of phase due to heat treatment. Diffusion mechanism. Time-temperature transformations of some important alloys. **[5]** **Polycrystalline:** Change of perfect polycrystallinity by mechanical processes, rolling Texture, The importance of its study, Poly figure and its determination. **[5]** **Quasi crystalline:** Quasi crystalline states of matter and their analysis. Nano materials, their characteristic properties and some of their uses. **[4]**							

Text Books, and/or reference material	**Text Books:** 1. S. K. Chatterjee, X-ray diffraction its theory and applications 2. B. D. Cullity, X-ray diffraction **Reference Books:** 1. M. M. Woolfson, An introduction to X-ray crystallography 2. L. V. Azaroff, Elements of X-ray crystallography 3. B. E. Warren, X-ray diffraction

Mapping of CO (Course Outcome) and PO (Programme Outcome)

POs / COs	PO1	PO2	PO3	PO4	PO5
CO1	3	2	1	1	3
CO2	3	1	2	2	3
CO3	3	1	3	1	3

Correlation levels 1, 2 or 3 as defined below :

1: Slight (Low)   2: Moderate (Medium)   3: Substantial (High)

<table>
<tr><td colspan="9">Department of Physics</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>PH9031</td><td>Optoelectronic Materials and Devices</td><td>PCR</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="3">Pre-requisites</td><td colspan="5">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="3">NIL</td><td colspan="5">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">• CO1: Demonstrate the working principle of laser, electro-optic devices and communication of light in optical fiber.
• CO2: Illustrate the mechanisms of absorption, amplification, broadening of radiation and techniques of generation of short pulsed laser radiation.
• CO3: Develop optic modulator by employing electro optic effect.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Basic principles of Laser: Broadening of energy levels, Absorption and amplification of light in a medium, population inversion and threshold condition for a laser, gain coefficient; Laser Rate Equations, 2-level, 3-level and 4-level Lasers, expression of Gain/Loss coefficient, Threshold population, Saturation Intensity etc. [9]
Line broadening Mechanisms: Spontaneous transition, Collision Broadening and Doppler Broadening. [3]
Resonators: Stability of resonators, g parameters, various types of resonators, Modes of Laser Radiation, Longitudinal and transverse modes, Mode selection techniques, Gaussian beam properties and Gaussian beam focusing. [7]
Different types of lasers: Principles of operations of Ruby Laser, He-Ne laser, Nd:YAG laser, Ti:Sa laser, CO_2 laser etc. [5]
Techniques for pulsed laser generation: Q-switching & mode-locking, methods of Q-switching, mechanisms and their comparison, methods of mode-locking. [5]
Electro-optic effect and acousto-optic effect: Electro and acousto-optic effects, electro-optic retardation, amplitude modulation, phase-modulation of light. [6]
Optical fibre waveguide: Optical fibre waveguide, step index and graded index fibre, multimode and single mode fibre, attenuation mechanisms in fibres etc. [7]</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">Text Books:
1. O. Svelto, Principles of Lasers
2. A. Ghatak and K. Thyagarajan, Optical Electronics, Cambridge University Press (2003)
Reference Books:
1. W. Koechner, Solid State Laser Engineering
2. A. Yariv, Quantum Electronics
3. J. Wilson and J. F. B. Hawkes, Optoelectronics: An introduction, Prentice Hall of India Pvt. Ltd., 2nd ed.-2004
4. Pallab Bhattacharya, Semiconductor Optoelectronic Devices, Prentice Hall</td></tr>
</table>

Mapping of CO (Course Outcome) and PO (Programme Outcome)

POs / COs	PO1	PO2	PO3	PO4	PO5
CO1	1	1	1		
CO2	1		2	2	1
CO3	3	1	3		2

Correlation levels 1, 2 or 3 as defined below :

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

<table>
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<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>PH9032</td><td>Nanomaterials – Science & Technology</td><td>PCR</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="2">Pre-requisites</td><td colspan="6">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="2">NIL</td><td colspan="6">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">On completion of the course the learner shall be able to:
• CO1: Introduce the concept of nanomaterials and associated changes in their properties from bulk
• CO2: Familiarize with various top down and bottom up methods for synthesis of nanomaterials.
• CO3: Explain the properties and applications of some recently developed nanostructures.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Introduction to Nanomaterials: Determination of energy Eigen values for 1D, 2D and 3D nanostructure by solving the Schrodinger equation. Calculation of density of state function of 1D, 2D and 3D nanostructures, properties nanomaterials. [4]
Bottom up methods for fabrication of nanomaterials:
Physical vapor deposition techniques - thermal evaporation, sputtering, e-beam evaporation, laser ablation technique, vapor-liquid-solid (VLS) deposition technique, Oblique Angle and Glancing Angle Deposition (GLAD),
Chemical Vapor Deposition, Molecular Beam Epitaxy [10]
Chemical methods:
Sol-gel technique [2]
Langmuir–Blodgett method. [2]
Top down methods:
Ball milling, Chemical and dry etching techniques, Optical and electron beam lithography, focused ion beam method. [8]
Inorganic and semiconductor nanostructures: From fabrication to application.
Other Nanotechnologies: Bio-nanotechnology, Micromachining tools for nanosystems, MEMS [8]
Special Nanostructures: Fullerene, Carbon nanotube, graphene and other 2D nanostructures, their properties and applications [8]</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">Text Books:
1. Introduction to Nanoscience and Nanotechnology, K K Chattopadhyay, AN Banrejee, PHI Learning, 2009.
2. Robert W. Kelsall , Ian W. Tlamley, Mark Geoghegan; Nanoscale Science and Technology

Reference Books:
1. S. C. Tjong, Nanocrystalline Materials, Elsevier
2. Claire Dupas, Philippe Houdy, Marcel Lahmani, Nanoscience Nanotechnology and Nanophysics.</td></tr>
</table>

	3. Hoshino & Mishima, Nanomaterials from Research to Applications, Elsevier 4. Graphene, Carbon Nanotubes, and Nanostructures: Techniques and Applications, James E. Morris, Krzysztof Iniewski , CRC Press, 2017.

Mapping of CO (Course Outcome) and PO (Programme Outcome)

POs / COs	PO1	PO2	PO3	PO4	PO5
CO1	3	2	3	3	2
CO2	2	3	3	2	3
CO3	2	3	3	2	2

Correlation levels 1, 2 or 3 as defined below :

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

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<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>PH9033</td><td>Mechanical Behavior of Materials</td><td>PCR</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="2">Pre-requisites</td><td colspan="6">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="2">NIL</td><td colspan="6">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">On completion of the course the learner shall be able to:
• CO1: Understand the mechanical properties of materials from a fundamental physics perspective.
• CO2: Classify different types of defects and infer their influence on the mechanical properties of the materials.
• CO3: Formulate different failure of materials and suggest ways to strengthen their mechanical properties.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Introduction to deformation behaviour: Concept of stresses and strains, engineering stresses and strains, Different types of loading and temperature encountered in applications, Tensile Test - stress - strain response for metal, elastic region, yield point, plastic deformation, necking and fracture, Bonding and Material Behaviour, theoretical estimates of strength of materials. [7]

Elasticity Theory: The State of Stress and strain, stress and strain tensor, tensor transformation, principal stress and strain, elastic stress-strain relation, anisotropy, elastic behaviour of metals, ceramics and polymers. [4]

Yielding and Plastic Deformation: Hydrostatic and Deviatoric stress, Octahedral stress, yield criteria and yield surface, texture and distortion of yield surface, Limitation of engineering strain at large deformation, true stress and true strain, effective stress, effective strain, flow rules, strain hardening, Ramberg-Osgood equation, stress - strain relation in plasticity, plastic deformation of metals [8]

Microscopic view of plastic deformation: crystals and defects, classification of defects, thermodynamics of defects, geometry of dislocations, slip and glide, dislocation generation - Frank Read and grain boundary sources, stress and strain field around dislocations, force on dislocation - self-stress, dislocation interactions, partial dislocations, twinning, dislocation movement and strain rate, deformation behavior of single crystal, critical resolved shear stress (CRSS), deformation of poly-crystals - Hall-Petch and other hardening mechanisms, grain size effect - source limited plasticity, Hall-Petch breakdown, dislocations in ceramics and glasses. [7]

Annealing: Introduction, Theory of Heat Treatment, Heat Treatment Environment, Different Heat Treatment Techniques, Fundamentals and Properties; Annealing, creation of twins by annealing, dislocation and annealing, annealing of Cold-Worked Metal, distinct processes of annealing: recovery,</td></tr>
</table>

	recrystallization and grain growth, texturing and its modification by annealing, strength and ductility in the cold-work-anneal cycle, hot-working processes and rapid cooling rate effects on grain size, commercial importance of annealing. **[5]** **Fracture:** fracture in ceramics, polymers and metals, different types of fractures in metals, fracture mechanics - Linear fracture mechanics -KIC, Elasto-plastic fracture mechanics - JIC, Measurement and ASTM standards, Design based on fracture mechanics, effect of environment, effect of microstructure on KIC and JIC, application of fracture mechanics in the design of metals, ceramics and polymers. **[6]** **Fatigue:** Deformation under cyclic load - Fatigue: S-N curves, Low and high cycle fatigue, Life cycle prediction, Fatigue in metals, ceramics and polymers. **[4]** **Creep:** Deformation at High temperature: Time dependent deformation - creep, different stages of creep, creep and stress rupture, creep mechanisms and creep mechanism maps, creep under multi-axial loading, microstructural aspects of creep and design of creep resistant alloys, high temperature deformation of ceramics and polymers. **[6]**
Text Books, and/or reference material	**Text Books:** 1. Mechanical Metallurgy – George E. Dieter 2. Principles of Heat Treatment of Steels- R.C. Sharma **Reference Books:** 1. Materials Science and Engineering – William D. Callister, Jr. 2. Mechanical Behavior of materials – Thomas H. Courtney 3. Mechanics of composite materials – Autar K. Kaw 4. Engineering Physical Metallurgy and Heat Treatment - Y. Lakhtein (Mir Publisher)

Mapping of CO (Course Outcome) and PO (Programme Outcome)

POs / COs	PO1	PO2	PO3	PO4	PO5
CO1	2	1	2	1	2
CO2	2	1	2	1	1
CO3	2	1	2	1	2

Correlation levels 1, 2 or 3 as defined below :

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Department of Physics								
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
PH9034	**Semiconductor Materials and Device Technology**	PEL	3	0	0	3	3

Pre-requisites	Course Assessment methods (Continuous (CT) and end assessment (EA))
NIL	CT+EA

Course Outcomes	On completion of the course the learner shall be able to: • **CO1:** Recall different preparation techniques of single crystal and IC fabrication. • **CO2:** Outline different advanced preparation techniques such as etching and lithography for high speed semiconductor devices. • **CO3:** Apply the fundamental knowledge of semiconductor materials to model dopant profile created by ion implantation technique.
Topics Covered	**Wafer fabrication:** Preparation of electronic grade Si from metallurgical grade Si, Czochralski (CZ) method, Float zone method, Silicon wafer fabrication. **[8]** **Oxidation techniques:** Oxidation techniques, Growth kinetics, Oxide growth measurements techniques, Defects in silicon, silicon dioxide, Interface defects, Point defect-based model for oxidation, Polysilicon, Si_3N_4 and Silicide formation. **[8]** **Lithography:** Optical lithography, Deep UV lithography, Extreme UV lithography, Electron beam lithography, plasma and x-ray lithography techniques. **[8]** **Wet etching:** Wet etching of Si and GaAs. Isotropic and anisotropic etching. Crystal orientation dependent etching. **[5]** **Dry etching:** Classification of plasma etching techniques, reactive ion etching, Inductive couple plasma reactive ion etching technique etc. **[5]** **Diffusion and Ion implantation**: Diffusion in polycrystalline materials, Ion implantation techniques, Modelling and measurement of dopant profiles, Overview of process flow for IC technology. **[8]**
Text Books, and/or reference material	**Text Books:** 1. S M Sze, VLSI Technology 2. B G Streetman & S Banerjee, Solid State Electronic Devices **Reference Books:** 1. S.K. Gandhi, VLSI fabrication principles

Mapping of CO (Course Outcome) and PO (Programme Outcome)

POs / COs	PO1	PO2	PO3	PO4	PO5
CO1	3	3	2	3	1
CO2	2	3	2	3	2
CO3	2	3	2	3	2

Correlation levels 1, 2 or 3 as defined below :

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

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<tr><td colspan="9">Department of Physics</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>PH9035</td><td>Materials for Energy Application</td><td>PEL</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="3">Pre-requisites</td><td colspan="5">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="3">NIL</td><td colspan="5">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">On completion of the course the learner shall be able to:
• CO1: Demonstrate different materials that can be utilized for energy applications.
• CO2: Explain the operation of different energy devices.
• CO3: Enable the students about the modern energy harvesting technologies.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Introduction: Overview of the energy/climate problem, alternative fuels, current hydrocarbon economy, shale oil, tar sands, methane clathrates [2]
Thermoelectric materials: Design of thermoelectric materials, thermal and electrical transport properties; model systems, synthesis of TE materials and TE devices [8]
Inorganic photovoltaic materials: Introduction and design of materials, inorganic photovoltaic materials Inorganic semiconductors for solar cell applications [6]
Organic photovoltaic materials: Dye sensitized and polymer solar cells, Small molecule solar, and other organic electronics [6]
Materials for hydrogen energy: Hydrogen production, transportation, storage, and use; materials for solar water splitting [5]
Materials for energy storage: Batteries, supercapacitors [5]
Fuel cells: Introduction, different types, SOFC, Bio fuel cells [5]
Other energy technologies: nuclear, geothermal, hydro, wind [5]</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">Text Books:
1. Materials for Sustainable Energy Applications: Conversion, Storage, Transmission, and Consumption, David Munoz-Rojas and Xavier Moya (Editors), CRC Press, 2016.
Reference Books:
1. Fundamentals of Materials for Energy and Environmental Sustainability, Ginley, David S. ; Cahen, D. Cambridge University Press, 2011.</td></tr>
</table>

Mapping of CO (Course Outcome) and PO (Programme Outcome)

POs / COs	PO1	PO2	PO3	PO4	PO5
CO1	2	1	2	2	3
CO2	2	1	1	2	3
CO3	2	1	1	2	3

Correlation levels 1, 2 or 3 as defined below :

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Department of Physics							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
PH9036	**Nuclear Reactor Materials**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NIL		CT+EA					

Course Outcomes	On completion of the course the learner shall be able to: • **CO1:** Illustrate nuclear energy released by nuclear fission and fusion. • **CO2:** Demonstrate the knowledge of a nuclear reactor, its classification and components. • **CO3:** Explain the safety protocol of nuclear reactor.
Topics Covered	**Nuclear Reaction Fundamentals:** Nuclear fission, separation energy and fissionability, fission cross section for slow and fast neutrons, energy release in fission, fission fragments and energy distribution, nuclear fusion and thermo-nuclear reaction. **[5]** **Neutron Physics and Diffusion Theory:** Properties of neutron, neutron sources, slowing down of neutrons, diffusion of thermal neutrons, diffusion equation, slowing down and diffusion, Critical size of reactor slabs, cubical, spherical and cylindrical reactors. **[5]** **Chain Reaction and Fuel Cycle:** Criticality factor, moderating ratio, four-factor formula, reactor kinetics, reactor poisons, nuclear fuel cycle, uranium enrichment, back end of fuel cycle. **[4]** **Nuclear Reactor fundamentals:** Classification of reactors, basic components. Outlines of BWR, PWR and FBR with their basic features and characteristics. **[4]** **Nuclear Reactor Components:** Nuclear Fuels (types, fabrication process, chemical & physical properties), moderators & coolants, control materials, construction materials (cladding). **[6]** **Pressure Vessel Design:** Material selection and design, steels for pressure vessels, interaction of radiation with matter and shielding, radiation & corrosion damages in pressure vessel, Fracture in reactor, etc. **[8]** **Thermal Design Principles:** Thermal Hydraulics Considerations, Energy Production and Transfer Parameters, Thermal Design Limits, Thermal Design Margin, Figures of Merit for Core Thermal Performance, Energy Release Parameters, Power Profiles in Reactor Cores, Heat Generation within the Fuel, Heat Generation in the Structure, Shutdown Heat Generation, thermal limits on reactor performance, thermal converters, fast breeders. **[6]** **Reactor Safety:** Safety design principles, Safety in operation, temperature and void coefficients, emergency cooling, hazards considerations, Chernobyl disaster **[4]**
Text Books, and/or reference material	**Text Books:** 1. Atomic & Nuclear Physics- S. N. Ghoshal 2. Nuclear Reactor Engineering – Glasstone & Sesonske

	Reference Books: 1. Nuclear Reactor Theory - Lamarsh 2. Nuclear Energy - David Bodansky 3. Thermal Hydraulics Fundamentals - Todreas and Kazimi 4. Comprehensive Nuclear Materials *I.-V.* - R. Konings 5. Materials for Nuclear Plants: From Safe Design to Residual Life Assessments- W. Hoffelner

Mapping of CO (Course Outcome) and PO (Programme Outcome)

POs / COs	PO1	PO2	PO3	PO4	PO5
CO1	3	2	2	2	1
CO2	3	2	1	2	1
CO3	2	2	1	2	3

Correlation levels 1, 2 or 3 as defined below :

1: Slight (Low)　　2: Moderate (Medium)　　3: Substantial (High)

Department of Physics								
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
PH9037	**Thin-film Materials Technology**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NIL		CT+EA					

Course Outcomes

On completion of the course the learner shall be able to:

- **CO1:** Recall the techniques of fabrication of different thin film materials.
- **CO2:** Illustrate different mechanisms of Vacuum Technology and epitaxial layer growth technology.
- **CO3:** Compare the working principles of PVD and CVD deposition systems and characterizations techniques of thin film.

Topics Covered

Growth and structure of films: General features. Nucleation theories Effect of electron bombardment on film structure. Post- nucleation growth Epitaxial films and growth. Structural defects. **[6]**

Preparation methods: Electrolytic deposition, cathodic and anodic films, thermal evaporation, cathodic sputtering, chemical vapour deposition. Molecular beam epitaxy and laser ablution methods. **[6]**

Vacuum science and techniques: Vacuum principles; Vacuum generation - Rotary vane pump, Diffusion Pump, Turbomolecular Pump (TMP), Cryo-Pump; Vacuum measurement - Thermal conductivity vacuum gauges, Ionization vacuum gauges. **[6]**

Thickness measurement and monitoring: Electrical, mechanical, optical interference, microbalance, quartz crystal methods.

Analytical techniques of characterization: Small angle X-ray diffraction, electron microscopy, high and low energy electron diffraction, Auger emission spectroscopy. **[6]**

Mechanical properties of films: Elastic and plastic behavior. Optical properties. Reflectance and transmittance spectra. Absorbing films. Optical constants of film material, Multilayer films, Anisotropic and gyrotropic films. **[6]**

Electric properties to films: Conductivity in metal, semiconductor and insulating films. Discontinuous films. Superconducting films. Dielectric properties. Magnetism of films: Molecular field theory. Spin wave theory. Anisotropy in magnetic films, Domains in films, Applications of magnetic films. **[9]**

Thin film devices: Fabrication and applications. **[3]**

Text Books, and/or reference material

Text Books:

1. K.L. Chopra, Thin Film Phenomena; McGraw-Hill
2. A. Goswami; Thin Film Fundamentals; New Age International Pvt. Ltd

Reference Books:

1. Milton Ohring, Materials science of thin films; Academic Press
2. Thin Films; Heavens; Dover Publications Inc.; 1991
3. Thin-Film Deposition: Principles and Practice; Smith; McGraw-Hill; 1995

	4. Handbook of Thin Film Technology; Maissel & Glang; McGraw-Hill; 1970

Mapping of CO (Course Outcome) and PO (Programme Outcome)

POs / COs	PO1	PO2	PO3	PO4	PO5
CO1	2	1	2	2	3
CO2	2	1	1	2	3
CO3	2	1	1	2	3

Correlation levels 1, 2 or 3 as defined below :

1: Slight (Low)   2: Moderate (Medium)   3: Substantial (High)

<table>
<tr><th colspan="9">Department of Physics</th></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PCR)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>PH9038</td><td>Biomaterials</td><td>PE</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="3">Pre-requisites</td><td colspan="5">Course Assessment methods: (Continuous (CT) and Midterm (MT) end assessment (EA)):</td></tr>
<tr><td colspan="3">Core courses of M.Tech AMST</td><td colspan="5">CT, MT, EA Examination</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">On completion of the course the learner shall be able to:
• CO1: Describe the various biomaterials and their unique properties used in industries.
• CO2: Understand the structure and function of various natural and artificial biomaterials such as polymers, composites, nano/bio interfaces etc.
• CO3: Apply the understanding gained for designing materials for biomedical applications.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">BASIC BIOLOGY PRINCIPLES: Self-assembly, hierarchy, and evolution – Multifunctionality, Self-organization and self-assembly, Adaptation, Evolution and convergence, Basic building blocks: biopolymers – Nucleotides and nucleic acid, Amino acids, peptides, and proteins, Polysaccharides and Lipids, Cells – Structure, Mechanical properties, Cell motility, locomotion, and adhesion, Biomineralization – Nucleation, Growth and morphology of crystals, Structures [11]

INTRODUCTION TO BIOLOGICAL MATERIALS. Silicate and calcium-carbonate-based composites, Calcium-phosphate-based composites, Biological polymers and polymer composites, Biological elastomers, Biological foams, Functional biomaterials. [10]

NANOBIOTECHNOLOGY. Nanostructures and Nanotechnology, Nano/Bio Interface; Synthesis of nanomaterials by biological methods; Biomimicry, DNA nanotechnology, Protein & Lipid nanotechnology, Bio-nanomachines, Carbon nanotube and its bio-applications; Biomedical aspects of nanomaterials, Nanopharmacology & drug targeting, Cellular uptake mechanisms of nanomaterials. [10]

BIOSENSORS AND DIAGNOSTIC DEVICES. Biosensors and Bioelectronics, sensors and actuators, Block diagram of Biosensor for electrical and nonelectrical signals, electrodes for biophysical sensing; The electrode-electrolyte interface, polarization, Electrode behavior and circuit models, body surface recording electrodes; Bio-potential measurements (EEG, ECG etc.), Brain-machine interfaces (neural stimulators); Biomaterials for Organ Replacement (prosthetics). [11]</td></tr>
<tr><td>Text Books, and/or</td><td colspan="7">Text books:

1) Biological Materials Science – Biological Materials, Bioinspired Materials and Biomaterials, Marc André Meyers and Po-Yu Chen, Cambridge University Press, 2014, ISBN-13: 978-1107010451
2) Molecular Biology of the Cell, B. Alberts, ISBN10 0815341067</td></tr>
</table>

reference material	**References and Further readings:** 1) Biomaterials Science: An Introduction to Materials in Medicine, Ratner, Buddy D., et al. 2nd ed. Burlington, MA: Academic Press, 2004. ISBN: 9780125824637. 2) Introduction to Biomedical Engineering, J.D. Enderle and J. Bronzino, 2012, Elsevier 3) Introduction to Biomedical Equipment Technology, JJ Carr, JM Brown, Pearson, 4th Ed. 4) Introductory Bioelectronics, R. Pethig and S. Smith, ISBN 9781119970873 5) Implantable Medical Electronics, V. K. Khanna, ISBN 978-3-319-25446-3

Mapping of CO (Course Outcome) and PO (Programme Outcome)

POs / COs	PO1	PO2	PO3	PO4	PO5
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Department of Physics							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
PH9039	**Non-Destructive Testing**	PCR	3	0	0	3	3

Pre-requisites	Course Assessment methods (Continuous (CT) and end assessment (EA))
NIL	CT+EA

Course Outcomes	On completion of the course the learner shall be able to: • **CO1:** Illustrate the basic knowledge of non-destructive testing. • **CO2:** Differentiate various defect/flaw types and select the appropriate NDT methods for the specimen. • **CO3:** Assess practical understanding of the optical interpretation and evaluation.
Topics Covered	**Introduction:** Non-Destructive Testing (NDT), Different NDT methods (Surface and Volume), NDT in Industry and Everyday Life. **[2]** **Optical Non-Destructive Testing:** Visual Optical methods (Borescope), Laser Speckle technique (Speckle Photography, Speckle Interferometry, Digital Speckle Pattern Interferometry), Holographic technique (Holographic Interferometry, Digital Holographic Microscopy), Shearography, Moire Technique, Photoelasticity, Fiber Optic Sensors, Infrared Thermography, Laser-Ultrasonics. **[12]** **Liquid penetrant Testing:** Basic principle, Types and properties of liquid penetrants, Developers, Methods of application, Advantages and limitations of various methods. **[3]** **Magnetic Particle Testing:** Basic theory of magnetism, Characteristics of magnetic fields, Magnetization methods, Field indicators, Particle application, Inspection. **[4]** **Eddy Current Testing:** Generation of eddy currents, Properties of eddy currents, Principle of eddy current testing, Applications (Crack detection, material thickness measurement, Coating thickness measurement, Conductivity measurement), Advantages and limitations. **[4]** **Ultrasonic Testing:** Basic principles of sound waves, Methods of ultrasonic wave generation, Piezoelectric transducer, Principles of Ultrasonic Inspection, Test techniques (pulse echo method, through transmission method, resonance method, contact testing and immersion testing, Normal beam and Angle beam), Applications, Advantages and limitations. **[6]** **Acoustic emission Testing:** Basic principle, Sources of acoustic emission, Source parameters. **[3]** **Radiographic Testing:** Basic principles of Radiography, X-ray source generation and properties, X-ray absorption and atomic scattering (Photoelectric, Compton, Pair production, Rayleigh, Photo disintegration), Film Radiography (X-ray film,

	characteristic curves), Radiographic Image Quality and Radiographic Techniques, Digital Radiography, Computed Tomography, Radiation Detectors and Radiation Safety (Radiation shielding) **[8]**
Text Books, and/or reference material	**Text Books:** 1. Rastogi, P.K. (ed.). Optical measurement techniques and applications. Boston: Artech House, 1997. ISBN 0890065160. 2. Nondestructive Testing, Louis Cartz, ASM International, 1995. **Reference Books:** 1. Edited by Sirohi R.S. Speckle Metrology Marcel Dekker 1993 ISBN 0-8247-8932-6. 2. B.P.C. Rao, Practical Eddy Current Testing, Alpha Science International Limited (2006). 3. N. A. Tracy, P. O. Moore, Non-Destructive Testing Handbook: Liquid Penetrant Testing, Vol.2, American Society for Nondestructive Testing, 3rd edition (1999). 4. Gasvik, K.J. Optical metrology. 3rd ed. Chichester: John Wiley & Sons, 2002. ISBN 9780470843000. 5. L. Schmerr and J. Song, Fundamentals of Ultrasonic Nondestructive Evaluation, Springer, 1998. 6. R. Halmshaw, Industrial Radiography: Theory and Practice, Springer, 2nd edition (1995).

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